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(72) Inventor FRANK RICHARD TOWNER

(19)

(54) IMPROVEMENTS IN OR RELATING TO DATA RECORDERS

(71) We, SPERRY RAND LIMITED, a British Company, of Remington House, 65 Holborn Viaduct, London, E.C.1., do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to data recorders having thermal protection. The invention has been evolved in connection with an aircraft data recorder (crash recorder) and for convenience will be discussed in connection therewith, but the invention is not limited to such data recorders.

Whilst it is desirable to protect all aircraft equipment both physically and thermally, it is particularly important that a crash recorder has maximum protection because it is the piece of equipment relied upon to give information pertaining to the failure of an aircraft and is clearly of no use if the recording medium used therein is likely to be destroyed as a result of the recorder being subjected to physical shock and/or fire resulting from impact of the aircraft with the ground, for example. Every improvement in performance of each new design of aircraft is accompanied by a demand for even greater thermal protection to ensure the all-important survival of the recording medium. In particular, military fighter aircraft present the greatest problems in that the space allocated for the crash recorder is always small, the weight of the recorder restricted and the temperature of a fire resulting from aircraft impact likely to be high because of the relatively small fuselage size which means that the recorder is inevitably close to the fuel tanks.

It is usual to surround a crash recorder with thermal insulation and to surround the thermal insulation with the primary physical protection in the form of a metallic casing. In order to meet the sustained high temperatures which the modern crash recorder must be capable of withstanding as discussed above, the thickness of the thermal insulation can be increased but this gives rise to a greater superficial area presented to the flames of a fire which in turn means a further increase in the thickness of the thermal insulation to achieve the required protection for the recorder. Thus the overall size and weight of the recorder unit often does not meet the specification in these respects.

In order to help reduce the bulk of the thermal protection, it has been proposed to employ an ablative or sacrificial material which may be removed wholly or in part by evaporation. In one case, water was used as the ablative material, the two important advantages of which are that it has a high value of latent heat of vaporisation, namely 538.7 calories per gram, and its boiling point of 100°C is ideal for protecting magnetic tape such as that made from the material known under the trade name "Mylar". However, there are two grave disadvantages with water in the context of aircraft crash recorders, the first is that it evaporates so that if this is not guarded against, the protection afforded suffers. The second disadvantage of water is that of its freezing point coupled with volume expansion on freezing, which means that in order to accommodate this, free space has to be provided in the recorder which increases the overall volume of the latter but more importantly, reduces the resistance to physical shock which is as critical a matter as that of thermal protection because under crash conditions, physical shock will normally precede fire and there is no point in providing adequate thermal protection if the recording medium is likely to be destroyed by the physical shock. Another ablative material which has been used in crash recorders is iodine but this too has certain disadvantages. Iodine vapour has a detrimental effect on the phosphor film of magnetic tape, the latent heat of vaporisation of iodine is only 23.75 calories per gram, whilst its boiling point is 184°C. These facts make iodine somewhat unsuitable for use in crash recorders and furthermore, the amount of iodine which would be required to effect adequate thermal protection would present weight problems.

According to the present invention there is provided a data recorder having thermal protection, the thermal protection comprising an ablative material located in and/or around the apparatus and being in the form of a chemical salt having water of crystallisation as part of its molecular structure.

Thus the invention is able to take advantage of the desirable ablative characteristics of water whilst avoiding the undesirable characteristics discussed. Furthermore, a chemical salt is more convenient to handle than a liquid and it also affords some measure of physical protection.

There are numerous chemical salts having water of crystallisation as parts of their molecular structures, some of which lose the water of crystallisation at a temperature of below 100°C, others of which lose said water at about 100°C, and the remainder of which lose said water at higher temperatures. Therefore, the selection of a salt for a particular apparatus depends on the highest temperature to which the apparatus can be subjected. In the case of a crash recorder using "Mylar" tape as the recording medium, protection against temperatures in excess of about 170°C (maximum) is required and a particularly useful chemical salt for this application is cupric sulphate ($Cu\ SO_4H_2O$) which has substantially one third of its total weight as water which boils off at a temperature slightly in excess of 100°C (approximately 104°C). Also, this salt will re-absorb water of crystallisation on cooling, which all salts of the type in question do not do.

In the case of a crash recorder using "Mylar" or other tape as the recording medium, the tape deck of the recorder still has to be surrounded by an amount of conventional thermal insulation, such as an insulant known under the Registered Trade Mark "Microtherm", or Min K, which in turn is surrounded by the primary physical protection, the thermal insulation and physical protection being apertured so as to allow the steam produced when the water of crystallisation of the chemical salt is boiled off, to be vented externally of the physical protection. Alternatively, the steam can be vented through the inevitable gaps between adjacent components of the physical protection, such as the lid or cover plate and the base. The chemical salt may be located in one or more cavities provided in one or more sides of the tape deck, each cavity being sealed at the junction with an associated aperture in the thermal protection with a material which is destructible due to the heat or pressure of the steam produced by the boiling off of the water of crystallisation.

The steam may be specifically routed to effect further cooling and it can be shown that maximum further cooling is achieved by directing the steam substantially mid-way through the thermal insulation, i.e. mid-way between the tape deck and the primary physical protection in the case of a crash recorder, assuming in all instances the use of an homogeneous thermal insulation.

Thus, according to a preferred feature of the invention the conventional thermal protection is divided into an inner portion and an outer portion of substantially equal thickness and spaced from each other, ducting being provided in the resulting gap such that steam produced by the boiling off of the water of crystallisation of the chemical salt is passed over the opposed surfaces of said inner and outer portions, whereby to effect cooling of the latter. In this connection, it will be appreciated that in the event of said boiling off occurring, the ambient temperature of the outer portion of the thermal protection will of necessity be much higher than that of steam, otherwise boiling off would not have taken place bearing in mind the basic thermal capacity of the crash recorder, so that the steam is able to effect cooling of said outer portion, and to some extent the inner portion, before being vented externally through the primary physical protection. In effecting the cooling, the temperature of the steam is raised and kinetic energy thus created in it causes the steam to expand and flow more quickly. In order to keep the pressure of the steam, and hence the recorder, substantially constant, the ducting is preferably arranged so that the steam flows into an ever increasing volume from the point at which it enters the gap between the inner and outer portions of the thermal protection to the point at which it is vented from the primary physical protection.

A crash recorder embodying the present invention will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a somewhat diagrammatic cross-section of the crash recorder,

Figure 2 is a perspective view of the crash recorder with a certain part removed, and

Figure 3 is an explanatory graph of temperature against time illustrating the invention.

Referring to Figures 1 and 2, the crash recorder is in the form of a unit indicated generally at 1 and comprising a tape deck 2, an outer metal casing 3, of steel or titanium for example, providing the primary physical protection for the recorder, and thermal insulation in the form of "Microtherm" disposed between the casing 3 and the tape deck 2 and surrounding the latter.

The thermal insulation comprises an inner portion 4A surrounding the tape deck 2, and an outer portion 4B surrounding, and spaced from, the inner portion and in contact with the inner surface of the casing 3. The gap 5 between the inner and outer portions 4A and

4B is conveniently 0.005 to 0.010 inch (0.125 to 0.250 mm) wide.

Opposed sides 6, 6′ of the tape deck 2 have respective cavities 7, 7′ formed therein which are filled with an ablative material 8 in the form of crystals of the chemical salt cupric sulphate ($Cu\ SO_4 5H_2O$). Apertures 9, 9′ are formed in the respective sides 6, 6′ of the tape deck communicating with the associated cavity 7, 7′, the apertures receiving one end of associated metal tubes 11, 11′ which pass through the inner thermal insulation 4A and terminate the gap 5. Each aperture 9, 9′ is sealed by a material 12, 12′ having a melting point of about 100°C, to prevent ingress of moisture to the cavities 7, 7′ which might spoil the crystals 8. A plurality of vent holes 13, 13′ are provided in respective opposed ends 10, 10′ of the casing 3.

Referring now more particularly to Figure 2, ducting is provided in the gap 5 with the objective of defining an ever-increasing volume into which the steam created in the event of the boiling off of the water of crystallisation of the crystals 8 flows from the point of entering the gap 5 through one of the tubes 11, 11′, to the point of exit through the associated vents 13, 13′, such that steam flows over the entire internal surface of outer insulation 4B, and to some extent over the internal surface of the inner insulation 4A, before being vented. The ducting is in the form of thin strips of stainless steel as seen in Figure 2 from which the outer insulation 4B and the casing 3 have been omitted for clarity. A strip 15 of stainless steel divides the gap 5 into two, the tube 11 terminating in the upper half of the gap 5, and the tube 11′ terminating in the lower half. Considering the upper half of the gap 5, the tube 11 terminates at the junction of two further stainless steel strips 16 which diverge along the associated internal end surface 14 of the outer insulation 4B and continue to diverge along the upper internal surface 17 of the outer insulation, the strips 16 terminating short of the opposite internal end surface 14′. A further stainless steel strip 18 extends from the strip 15 at a point mid-way along the portion thereof on the internal surface 14′, to a point short of the junction of the upper internal surface 17 and the internal end surface 14.

Thus, steam issuing from the tube 11 flows into a portion of the gap 5 defined by the two strips 16 and having an ever-increasing volume except for when the strip 18 is reached which serves to divide the steam between two halves of the upper half of the gap 5. However, thereafter the volume again ever increases as can be seen if the righthand path taken by the steam is considered, as seen in Figure 2. This path is that defined by the right-hand strip 16 and the strip 18, these strips guiding the steam over part of the upper internal surface 17 of the outer insulation 4B, over part of the internal end surface 14′, around that end surface to the adjacent internal side surface and around the end of the strip 16 over the remainder of the upper surface 17. It will be seen that the strip 16 under consideration and the portion of the strip 18 disposed along said adjacent internal side surface of the outer insulation 4B diverge with respect to each other, whereby the volume of the relevant portion of the gap 5 continues to increase. Finally, the steam is guided over the right-hand portion of the internal end surface 14 of the outer insulation 4B, as seen in Figure 2, and out through the associated vents 13. The described right-hand path for the steam is indicated by the arrows 19, arrows 21 indicating the corresponding left-hand path.

The ducting in the lower half of the gap 5 defines similar right- and left-hand paths for the steam as described for the upper half, the corresponding strips of stainless steel being referenced 16′ and 18′.

In the event of the crash recorder 1 being subjected to a fire, as a result of aircraft impact for example, the temperature of the casing 3 first increases, the rate of increase depending on the thermal capacity thereof. The thermal insulation 4 is also subjected to an increase in temperature, as in turn is the tape deck 2. If the temperature of the fire is high enough and/or the fire is sustained for an appropriate period of time, the tape deck 2 will eventually reach a temperature of 100°C at which the seals 12, 12′ melt so that the cavities 7, 7′ are in direct communication with the respective tubes 11, 11′. As the tape deck temperature continues to rise, the water of crystallisation of the cupric sulphate crystals 8 will start to be boiled off (at about 104°C) and the steam will issue from the tubes 11 and 11′ and follow the paths described above which cover the entire internal surface of the outer insulation 4B. Thus the steam will effect cooling of the thermal insulation 4A, 4B. The kinetic energy thus imparted to the steam will cause the latter to expand and increase its rate of flow but the arrangement of the ducting strips 15, 16, 16′, 18 and 18′ providing an ever-increasing volume of the steam to flow into results in the pressure of the steam remaining substantially constant. It is important that the pressure does not increase otherwise the boiling point of the water of crystallisation of the crystals 8 will rise, whereby the ceiling of thermal protection rises, possibly to a point at which "Mylar" tape would no longer be protected.

Figure 3 of the drawings shows the result of a laboratory test giving rise to a graph of temperature against time for a model of a crash recorder having a casing 3, thermal insulation 4A, 4B and crystals 8 but no ducting, the tape deck 2 being subjected to an

increase in temperature from about 15°C to about 135°C by the application of direct heat to the casing. The curve illustrates that in these particular circumstances there was an initial, substantially linear, increase in temperature following which there was a period of almost four hours during which the temperature was constant as a result of the boiling off of the water of crystallisation of the ablative material (in this case sodium sulphite). Thereafter, the temperature increased again. Thus the principle underlying the present invention was confirmed.

As mentioned hereinbefore, a chemical salt having water of crystallisation as part of its molecular structure may be used as the ablative material, the choice depending on the thermal limit of protection required. However, it has been found that the following chemical salts, in addition to the preferred cupric sulphate, may be particularly useful with the present invention.

	Salt	Formula
1.	Aluminium ammonium sulphate (Ammonium alum)	$NH_4Al(SO_4)_2 12H_2O$
2.	Chromic sulphate	$Cr_2(SO_4)_3 15H_2O$
3.	Sodium sulphite	$Na_2SO_3 7H_2O$
4.	Chromic potassium sulphate (Chrome alum)	$KCr(SO_4)_2 12H_2O$
5.	Tetra sodium pyrophosphate	$Na_4P_2O_7 10H_2O$
6.	Hydrated calcium peroxide	$CaO_2 8H_2O$
7.	Tri basic sodium orthophosphate	$Na_3PO_4 10H_2O$

The crash recorder described with reference to Figures 1 and 2 employs "Mylar" tape as the recording medium and the arrangement is such that the cupric sulphate in the cavities 7, 7′ will afford, in conjunction with the thermal protection 4A, 4B and the inherent thermal capacity of the casing 3 and tape deck 2, thermal protection necessary to preserve the "Mylar" tape in the event of very high ambient temperatures. For example, the "Mylar" tape is expected to be preserved when 50% of the exterior surface of the casing is subjected to a temperature of 1100°C for 30 minutes, which is the specification laid down for this particular crash recorder. As far as "Mylar" tape is concerned, the upper limit of the temperature to which it can be subjected without data thereon being effectively or literally destroyed is of the order of 170°C. The amount of crystals 8 in the cavities 7, 7′ will depend on the thermal capacities of the casing 3, thermal insulation 4A, 4B and tape deck 2 which in turn are governed by various factors, such as dimension, as well as on the temperature above which the interior of the tape deck 2 must not be permitted to rise. It should be noted that the gap 5 does not produce any significant reduction in the resistance of the recorder unit to physical shock, the gap being of such small dimension that the casing 3 will flex, without damage thereto, to take up this space upon being subjected to an appropriate physical shock.

In alternative arrangement, the tape deck 2 may have one or more shallow recesses provided on its external surface in which the ablative material is placed, preferably secured in position by a cement. Vents are provided in the primary physical protection, sealed similarly to the apertures 9, 9′, through which steam escapes. In this construction, the preferred feature of passing the steam over the entire internal surface of the inner/outer thermal protection is not employed.

WHAT WE CLAIM IS:—

1. A data recorder having thermal protection, the thermal protection comprising an ablative material (as herein defined) located in and/or around the recorder and being in the form of a chemical salt having water of crystallisation as part of its molecular structure.

2. A data recorder according to claim 1, wherein the ablative material is selected from the group comprising cupric sulphate, aluminium ammonium sulphate, chromic sulphate, sodium sulphite, chromic potassium sulphate, tetra sodium pyrophosphate, hydrated calcium peroxide and tri basic sodium orthophosphate.

3. A data recorder according to claim 1 or 2 and comprising a tape deck surrounded by thermal insulation, with the thermal insulation being surrounded by a primary physical protection, steam resulting from any boiling off of the water of crystallisation of the ablative material being vented through the primary physical protection.

4. A data recorder according to claim 3, wherein the primary physical and thermal insulation are apertured to provide vents for the steam.

5. A data recorder according to claim 3, wherein the thermal insulation comprises an inner portion and an outer portion of substantially equal thickness and spaced from each other, ducting being provided in the gap between said inner and outer portions such that steam produced by the boiling off of the water of crystallisation of the ablative

material is passed over the opposed surfaces of said inner and outer portions of thermal insulation, thereby cooling the latter.

6. A data recorder according to claim 5, wherein the ducting is arranged so that steam flows into an ever increasing volume from the point at which it enters the gap between said inner and outer portions of the thermal insulation to the point at which it is vented from the primary physical protection.

7. A data recorder according to claim 5 or 6, wherein the gap between said inner and outer portions is from 0.005 to 0.010 inch wide.

8. A data recorder according to any of claims 5 to 7, wherein the ablative material is disposed in one or more cavities provided in the tape deck, the cavities being sealed by a material destructible by the heat or pressure of the steam produced by the boiling off of water of crystallisation of the ablative material.

9. A data recorder according to claim 8, wherein one or more tubes are provided to convey any steam from the or each cavity to said gap.

10. A data recorder substantially as herein particularly described with reference to the accompanying drawings.

Agent for the Applicants:—
J. SINGLETON,
Chartered Patent Agent.

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1498177 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

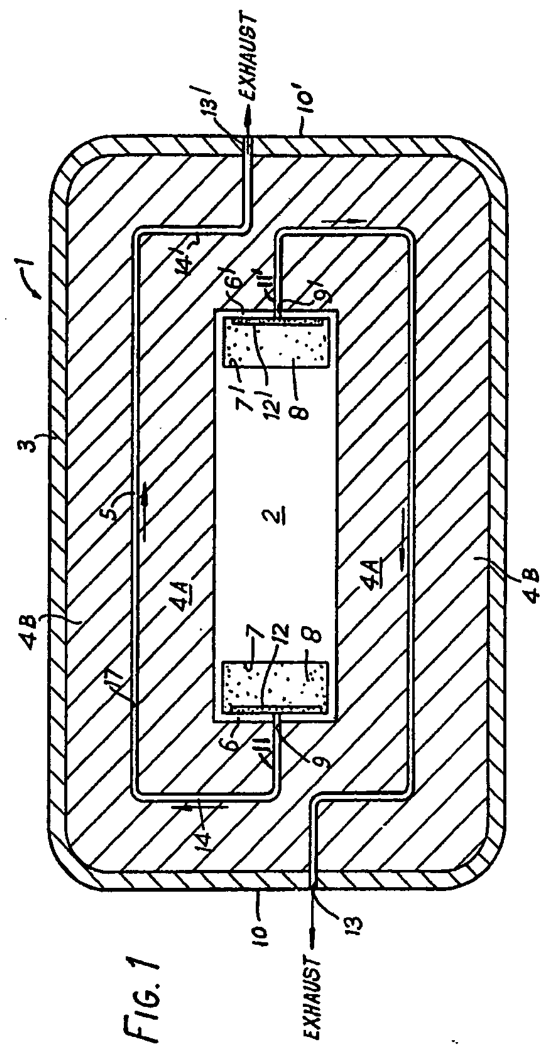

FIG. 1

1498177 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

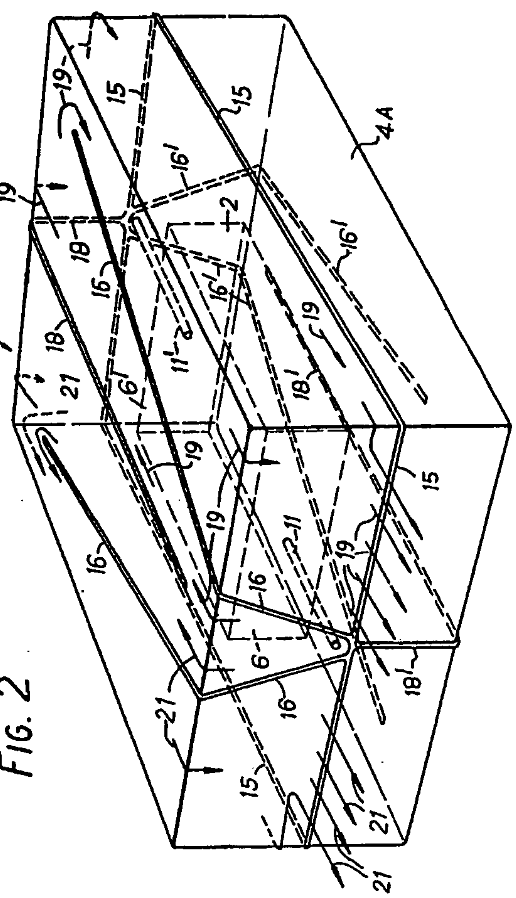

FIG. 2

1498177 COMPLETE SPECIFICATION

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Sheet 3

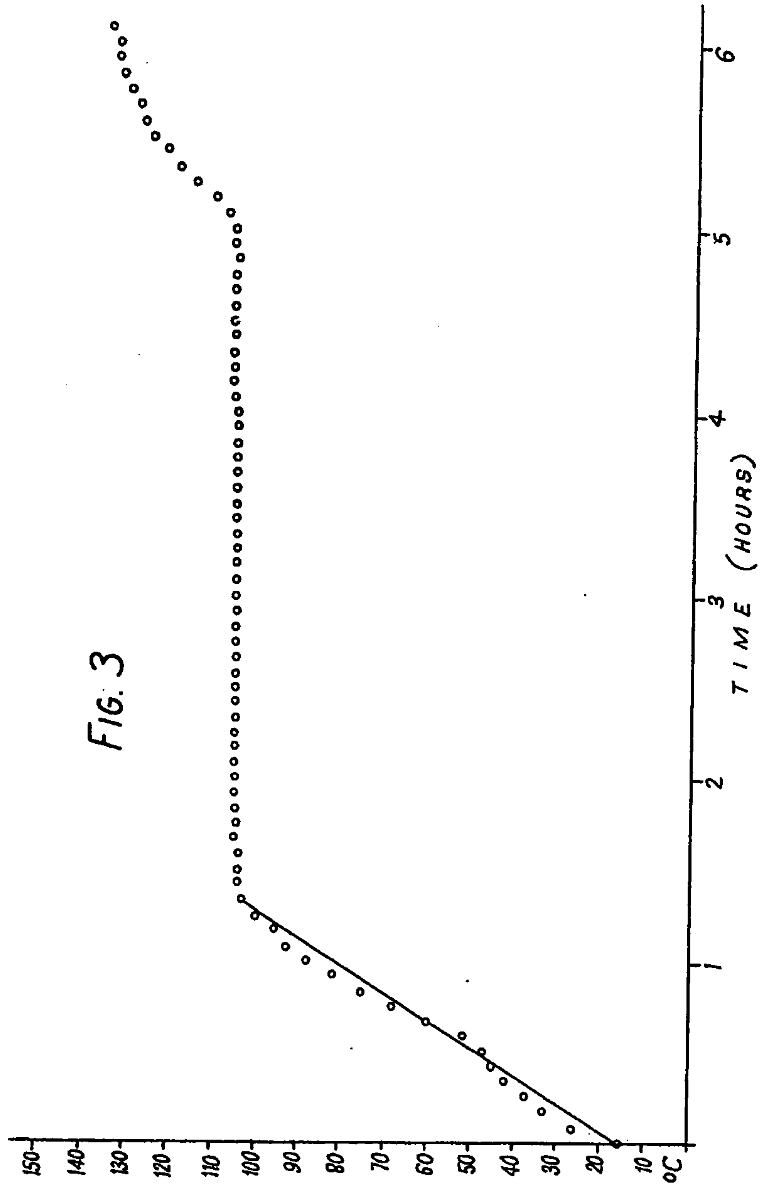

FIG. 3